MULTI-VOLTAGE ON-BOARD ELECTRICAL SYSTEM

[Background Information] **FIELD OF THE INVENTION**

The present invention relates to a multi-voltage on-board electrical system, in particular a multi-voltage on-board electrical system for a motor vehicle [according to the definition of the species of the main claim.]**.**

[Background Information] **BACKGROUND INFORMATION**

In on-board electrical systems having a plurality of electric consumers, e.g., in on-board electrical systems for motor vehicles, there [is the] **may be a** problem **in** that a 12V voltage is no longer sufficient for the power supply. Since some of the consumers [are to] **may** be supplied with a voltage higher than 12V, multi-voltage on-board electrical systems having two different voltage levels have become [known] **conventional** - a first voltage level, which is at +12V to ground, and a second voltage level at +36V , these voltages both being nominal voltages. The connection between the two voltage levels [is] **may be** established with the help of a d.c.-d.c. converter.

Such a multi-voltage on-board electrical system in a motor vehicle is described in [Unexamined] German **Published** Patent **Application No.** 198 45 569. The electric power [is] **may be** generated in this on-board electrical system with the help of a three-phase generator which [is] **may be** driven by the engine of the vehicle and [delivers] **may deliver** an output voltage of 42V (charging voltage). A 36V (nominal voltage) battery [is] **may be** charged with this charging voltage. A 12V battery [is] **may be** supplied with a charging voltage of 14V via a d.c.-d.c. converter.

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MARKED-UP VERSION OF SUBSTITUTE SPECIFICATION

The electric consumers may be connected to the two batteries via suitable switches, the 12V battery supplying the traditional on-board electrical system consumers, e.g., incandescent lamps, while the 36V battery [is] **may be** used to supply high-power consumers, e.g., defrosters. With the [known] **conventional** on-board electrical system, the negative terminals of the two batteries [are] **may be** at the same ground potential. [Unexamined] German **Published** Patent **Application No.** 198 45 569 [does] **may** not describe any measures for preventing a short circuit between the 12V and 36V voltage level or the 14V and 42V voltage level.

[Advantages of the Invention] **SUMMARY OF THE INVENTION**

[The] **An** on-board electrical system according to the present invention [having the features of Claim 1 has the advantage that the possibilities for] **may largely avoid** a short circuit occurring between the two voltage levels [are largely avoided]. However, if a short circuit does occur between the two voltage levels, its effects [are] **may be** attenuated and it [is] **may be** indicated or corrected as soon as possible. At the same time, the consumers supplied with the lower voltage [are advantageously] **may be** protected from the effects of the short circuit.

[These advantages are] **This may be** achieved by [designing] **configuring** a multi-voltage on-board electrical system [having the features of Claim 1] so that [means] **an arrangement** for short-circuit protection [are] **is** provided between the two voltage levels, [these means] **the arrangement** preventing a short circuit while also reducing the potential differences between the two voltage levels if a short circuit should nevertheless occur. The [means] **arrangement** for short-circuit protection **may** also include measuring devices which may determine load currents. By analyzing the currents measured, it [is] **may be** possible to localize a short circuit and

indicate it through suitable [display means.] **a display arrangement.**

[Additional advantages of the present invention are achieved through the measures characterized in the subclaims. These measures yield the advantage of minimizing] **The present invention may include measures to minimize** the points where an unprotected short circuit may occur[; this is]**. This may be** achieved, for example, by reducing the line length and through suitable combination of consumers of the same voltage level. In addition, short circuits [are] **may be** detected rapidly [to advantage] and [are] **may be** eliminated by shutting down the 36V or 42V consumer at the voltage source. During the time until shutdown of the driving 36V or 42V consumer, the low-voltage system [is] **may be** protected by design measures, e.g., by an overvoltage protection or by removing the higher voltage via robust consumers. Such robust consumers, which withstand voltages even higher than 12V, **may** include, for example, electric heaters or the 12V or 14V battery itself. By reducing the unprotected 36V or 42V lines through a suitable combination of voltage converter and signal-power distributor (SLV), [it is possible to further reduce the short-circuit probability in an advantageous manner; the same thing is also true of a design] **the probability of a short circuit may be further reduced. The same thing may also apply to a configuration** featuring a spatial proximity of signal-power distributor (SLV) and 36V or 42V battery.

[Another advantageous possibility of reducing the] **The** probability of a short-circuit [is to protect] **may also be reduced by protecting** the unprotected 42V lines via additional signal-power distributors (satellite signal-power distributors (satellite SLV)) and d.c.-d.c. converters via a master-signal-power distributor system (master SLV).

[The] **An** on-board electrical system according to the present invention [yields the possibility of] **may yield** an overall concept for a multi-voltage on-board electrical system [in an advantageous manner], having a battery fuse protection even in the event of a crash and fuse protection for the lower (14V) subsystem for the event of a short circuit between the two subsystems. Even in the event of a short circuit, consequential damage with regard to the battery [is avoided in an advantageous manner. It is also advantageous that a] **may be avoided. A** "healthy battery" [is] **may be** ensured by bracketing the 14V subsystem while it **may** simultaneously [functions] **function** as a sacrificial consumer to secure the overcurrent in the event of a short circuit. Self-sensing line switches (e.g., sensfets) in the 42V subsystem [are advantageous] **may be used** for short-circuit detection and shutdown.

Use of an active voltage limitation having a MOS output stage [is also advantageous and makes it possible to] **may** eliminate the additional complexity in polarity reversal.

[Drawing

Embodiments of the present invention are illustrated in the drawing and explained in greater detail in the following description. Specifically,] **BRIEF DESCRIPTION OF THE DRAWINGS** Figure 1 shows as an example **of** a dual-voltage on-board electrical system in the case of a short circuit between the two voltage levels[;]**.**

Figure 2 shows a first simple on-board electrical system architecture[;]**.**

Figure 3 shows an expanded on-board electrical system architecture, which [is] **may be** improved in comparison with that shown in Figure 2[, and]**.**

Figure 4 shows a diagram of an overall concept having battery fuse protection for the event of a crash and of a short-circuit.

Figure 5 shows an example of another protective circuit.

[Description] **DETAILED DESCRIPTION**

Figure 1 shows a schematic block diagram of the components of a dual-voltage on-board electrical system of a motor vehicle which [are] **may be** essential for an understanding of the present invention. Specifically, generator G, e.g., a claw-pole three-phase generator driven by the vehicle engine is shown. Generator G delivers an output voltage U0 of 42V, for example, which is used directly to charge battery B1 having a nominal voltage of 36V. The line resistance between generator G and battery B1 is symbolized by resistors R1 and R2. The consumers that are to be supplied with voltage U0 are connected to generator G via signal-power distributor V1. Specifically, three consumers R6, R7 and R8 are shown, connectable to generator G over semiconductor switches H1, H2 and H3, for example. According to the design, these semiconductor switches H1, H2 and H3 have inverse diodes D1, D2 and D3 and internal resistors R3, R4 and R5.

A second battery B2 is charged by generator G via a d.c.-d.c. converter W1. D.c.-d.c. converter W1 converts voltage U0=42V into a voltage U1=14V suitable for charging battery B2 having a nominal voltage of 12V. Voltage U1 is supplied by voltage converter W1 to battery B2 via switch S1 and the line having line resistance R9. Resistance R9 also includes the internal resistance of battery B2.

Battery B2 supplies consumers which require a lower voltage, e.g., 12V or 14V. The connection is via signal-power distributor V2. These consumers are labeled as R13, R14 and

R15 and may be connected to the system via semiconductor switches H4, H5 and H6 having inverse diodes D4, D5 and D6, respectively. The line resistances between consumers R13, R14 and R15 are labeled as R10, R11 and R12.

The consumers that are to be supplied with 12V or 14V over SLV V2 also include the series connection of a Zener diode Z1 and another diode D7, which together form an overvoltage protection.

The consumers for one or the other voltage level are selected according to the voltage requirements for their optimal operation. The starter may be connected either to the 12V battery or the 36V battery, for example.

When using semiconductor switches on the 14V side, the switch having the short-circuited 14V load becomes conducting via the inverse diode, which is always present, of the respective semiconductor switch and thus connects all the 14V consumers to 42V, so there is a risk to the consumers that are not designed for the higher voltage. Figure 1 illustrates such a short circuit. A resistor RK situated on the voltage side between resistors R8 and R13 represents a short circuit which is either to be avoided according to the present invention or whose effects are at least to be mitigated. How a short circuit symbolized by resistor R16 may be prevented or its effects minimized will be explained in greater detail below.

Figure 2 illustrates another **<u>example</u>** embodiment of an on-board electrical system architecture. This again shows generator G, but in addition Figure 2 also indicates the regulation of the generator with the help of pulse-controlled inverter elements, which are designed as a pulse-controlled inverter bridge PWR for a three-phase generator in a [known] **<u>conventional</u>** manner. In this case, voltage U0 occurs at the output of pulse-controlled inverter bridge PWR. Voltage U0 is supplied

to various components of the on-board electrical system according to Figure 2, the connection of these components being at a point P1 in the selected **example** embodiment. At this point P1, intelligent battery terminal IBK1 is connected via which battery B1 is supplied with voltage U0. In addition, consumers V1 may also be connected directly to intelligent battery terminal IBK1 and thus connected to battery B1. From point P1, d.c.-d.c. converter W1 and signal-power distributors SLV1, SLV2 through SLVn are also supplied with voltage U0, and they may in turn supply other consumers, only consumers R16, R17 and R18 of which are shown here. At the input, the signal-power distributors (SLV) are interconnected on the 36V and 12V side or on the 42V and 14V side, so they are connected in parallel to voltage converter W1. At the output, the signal-power distributors supply power supply voltage U0 and U1 for consumers R16, R17, R18 and R19, R20, R21, respectively.

The low-voltage side of voltage converter W1 on which voltage U1 is 12V or 14V leads over intelligent battery terminal IBK2 to battery B2. Additional consumers V2 may be connected via switch S3 to intelligent battery terminal IBK2 having overvoltage protection and thus directly to battery B2.

The actual 42V and 14V voltage levels are formed by the corresponding sides of the signal-power distributors having respective consumers R16, R17 and R18 symbolically for the 42V voltage level and R19, R20 and R21 symbolically for the consumers of the 14V voltage level.

The example of an on-board electrical system architecture illustrated in Figure 2 [is] **may be** a standard [design] **configuration** which [is] **may** improved with the arrangement illustrated in Figure 3. The difference between the **example** embodiment according to the present invention as illustrated in Figure 3 and that according to Figure 2 is that voltage

converter W1 and signal-power distributor SLV1 are combined and form converter W2. Signal-power distributor SLV1 of converter W2 is then connected to other signal-power distributors SLV2 through SLVn and thus forms a master SLV which protects satellite signal-power distributors SLV2 through SLVn. The satellite SLV may have their own d.c.-d.c. converters, the SLV and the d.c.-d.c. converters then being combined at least in part. The signal-power distributors **may** include[, if necessary,] a separate microprocessor which performs the required control measures automatically.

In the **example** embodiment according to Figure 3, for example, voltage converter W1 is combined with signal-power distributor SLV1 to form a common component W2. Signal-power distributor SLVn is assigned its own d.c.-d.c. converter DC/DCn, and signal-power distributor SLV2 is supplied with power and controlled directly by signal-power distributor SLV1. There [are] **may** also **be** other possible connections to the signal-power distributors. The other components of the on-board electrical system of the embodiment according to Figure 3 correspond to the embodiment according to Figure 2.

As shown in Figure 1, additional faults or short circuits may occur in a dual-voltage on-board electrical system, e.g., in an on-board electrical system having 14V/42V voltage levels to ground, in addition to the [known] short circuits to ground, namely short circuits between 14V and 42V. If, as shown in Figure 1, semiconductor switches H1 through H6 are used for connecting consumers to the system or disconnecting them, inverse diodes D1 through D6 are [automatically] also present and [must] **may need to** be taken into account. When using semiconductor switches having inverse diodes on the 14V side, the switch having the short-circuited 14V consumer becomes conducting via the respective inverse diode and connects all 14V loads to 42V. All 14V consumers are thus at 42V in the case of a single short circuit and [are] **may be** at risk

because they are not usually [designed] **configured** for this. Thus, the possibility of a 14V/42V short circuit [is to] **may** be reduced according to the present invention, and in the event a short circuit nevertheless occurs, at least the 14V consumers [are to] **may** be protected. A few protective measures [are] **may be** achieved by design features in the on-board electrical system illustrated in Figure 2[, but the most advantageous]**. An example** embodiment according to the present invention of an on-board electrical system architecture [with which all the advantages of this invention may be achieved] is illustrated in Figure 3.

In an arrangement according to the on-board electrical system architecture illustrated in Figure 2, various lines may lead from the 36V or 42V battery B1 to generator G, d.c.-d.c. converter W1 and signal-power distributors SLV1 through SLVn. These lines are not protected by any switches or fuses except for intelligent battery terminal IBK1. A short circuit of one of these lines to a 14V consumer R19, R20, R21 or V2 [cannot] **may not** be corrected by a shutdown on 42V, but [there is the possibility of performing] the shutdown of the battery **may be performed** via intelligent battery terminal IBK1[; however]**. However**, then the entire on-board electrical system [is] **may be** shut down. Since signal-power distributors SLV1 through SLVn are usually distributed over the entire vehicle and are situated in the engine space, the cockpit or the trunk, for example, this [results] **may result** in substantial cable lengths which **may** result in a relatively high probability of a short circuit.

A first measure to reduce the probability of a short circuit on unprotected 42V lines is to combine them with, or at least [guarantee] **ensure** their spatial proximity to, a central signal-power distributor SLV1 having d.c.-d.c. converter W1 or an additional d.c.-d.c. converter. This forms a new control

unit within which the lines and plugs are designed so that the 14V areas and the 42V areas are separated by the maximum possible distance.

A second measure is the spatial proximity of the battery and the respective d.c.-d.c. converter combination. As an alternative to that, pulse-controlled inverter PWR of generator G may be combined with d.c.-d.c. converter W1 or at least a spatial proximity between these parts may be [guaranteed] **ensured**.

A third measure which is made possible with the **example** embodiment according to Figure 3 is to connect the additional signal-power distributors not directly to the battery but instead to protect them as satellite signal-power distributors by a master signal-power distributor.

As an alternative, central or decentralized, locally distributed d.c.-d.c. converters may also be used to supply the 14V side of the on-board electrical system. Decentralized d.c.-d.c. converters reduce the length of unprotected 14V lines and thus **may** also reduce the probability of these lines coming in contact with 42V lines. If this alternative is selected, the protection may in turn be implemented via the master signal-power distributor, and the d.c.-d.c. converter may be combined with a satellite signal-power distributor to form a separate control system. All these measures **may** contribute toward reducing the probability of a short circuit. However, if a short circuit nevertheless occurs, at least measures [are] **may be** initiated to reduce the effects of the short circuit according to the present invention.

In the case of a 14V/42V short circuit such as that illustrated in Figure 1, the 42V power supply voltage is first applied to the short-circuited 14V consumer. Then the 42V voltage is applied via the respective inverse diode of the

semiconductor switch in the signal-power distributor to all 14V switches, which are protected from the overvoltage by switching through. Therefore, after a short period of time, a voltage of 42V is applied to the disconnected 14V consumers, but this voltage may result in damage to the consumers if no countermeasures are taken. One possibility of preventing this damage is to use reverse current-protected switches instead of semiconductor switches having inverse diodes, in which case, however, it [becomes] **may become** difficult to locate the short circuit on 42V.

Another alternative in the event of a short circuit is to connect a strong 14V consumer ("sacrificial consumer"), e.g., one of resistors R19, R20, R21, and to implement a targeted reduction in the resulting voltage in the system. The high current established due to the sacrificial consumer, which also flows through the supplying 42V consumer, offers the possibility of actively detecting the supplying consumer by detecting the overcurrent with the help of a current measurement. After detection of the consumer, it may be disconnected or with the help of an implemented fuse function, a targeted shutdown may be performed on the 42V consumer. Shutdown of the supplying 42V load [is in any case the] **may be a** response which repairs the system in [the most] **an** effective and efficient manner.

To detect the overcurrent in the supplying 42V load, i.e., 42V consumer, the current through the 42V may be sensed in the signal-power distributor, e.g., in the master SLV in a lower-level program loop in a very short clock cycle, and if an overcurrent is detected, a disconnect may be performed. The shorter the period of time between the occurrence of the fault and disconnection of the supplying load, the shorter is the time during which an overvoltage occurs at the 14V consumers and an undervoltage at the 42V consumers.

If the short circuit has occurred at a 42V consumer which is supplied with power by a satellite signal-power distributor SLV, the master signal-power distributor SLV [must not disconnect] **may be required to avoid disconnecting** the line to satellite SLV immediately, but instead it [must] **may be required to** allow time for correction of the fault. If this does not occur within a specified period of time, the master SLV [must] **may** nevertheless **be required to** disconnect the satellite SLV because then the short circuit has presumably occurred on the supply line of the satellite SLV.

Since this period of time is not infinitely short, the sacrificial consumer [should] **may** be designed accordingly so that it is not damaged by the overvoltage or the resulting current. One possibility [is] **may be** to insert an overvoltage protection element such as an active surge voltage protector similar to a load-dump protector which keeps the voltage within a defined range.

An alternative is to use the 12V battery as a sacrificial consumer. The 12V and 36V battery (nominal voltage) [must be designed] **may be required to be configured** accordingly, so that neither battery is damaged for the period of time required for detection and disconnection of the supplying load, and so that the voltage in the system is able to stabilize at a level that will not damage either the consumers of the 42V voltage level or those of the 14V voltage level.

Figure 4 shows another overall concept of an on-board electrical system. This on-board electrical system which is designed as a 14/42 volt on-board electrical system (charging voltage), i.e., a 12/36 volt system (nominal voltage) includes a back-up fuse concept, a battery state monitor, [preferably] **may be** integrated into the power management, and an overcurrent disconnect integrated into the individual switches of the 42V subsystem.

The overall design having electrical battery management (EBM) and electrical power management (EEM) [has] **includes** a generator G which may also be designed as a starter/generator and [preferably includes] **may include** bidirectional d.c.-d.c. converters, a battery back-up fuse concept, a power management and signal-power distributor (SLV) for the 14V and 42V subsystems. The 14V subsystem **may** also [includes] **include** a starter St which is needed if only a generator is connected to 42V, or an auxiliary starter HSt, which [is] **may be** sufficient in the case of a starter/generator at 42V. Starter St [should] **may** be designed for an external start and the auxiliary starter [should] **may** be designed to support the starter/generator in the case of low-temperature start.

The back-up fuse [design has] **configuration includes** one unit per battery, and it [should] **may** be situated close to the B+ terminal (B+ pin) of the battery or in its immediate proximity. It contains fuses to the generator or the starter/generator or starter St, an electronic switch to the on-board electrical system and components for detection of the parameters of the battery status (charge status SOC and age of the battery SOH). The actually battery status calculation [is preferably] **may be** performed in the power management system, in addition to its actual function of protecting the battery charge state in both subsystems by influencing the drive train and consumers. All the components communicate with one another over a vehicle body bus (e.g. a CAN bus). The overall coordination is integrated into the power management system.

With the back-up fuse design described here, one compact unit may [advantageously] have integrated into it the actual back-up fuses for the generator and the d.c.-d.c. converters and starters, the switches for disconnecting the on-board electrical system in the event of a crash (activated by the airbag via the CAN) and components for detecting the battery status (IB, UB, TB). Because of the selected arrangement, no

inversely switched additional power circuit-breakers [are] **may be** needed, so the voltage drop across the semiconductor switch, [preferably] **e.g.** a power MOSFET, is lower.

Another [important] feature of the overall fuse design is contained in the switches (SLV) of the 42V subsystem. They are designed as sensfets, for example. The actual overcurrent detection is to be designed as HW, so this guarantees that a disconnection of the short-circuit path in the 42V subsystem in the microsecond range is possible. This is important so that the 14V components affected by the short circuit [are] **may be** reliably protected.

The 12/14-volt battery whose state is monitored [is] **may be** capable of reliably bracketing the 14V subsystem at a harmless level until shutdown on the 42-volt side occurs. In addition, this [guarantees] **ensures** that a definitely detectable overcurrent in the shorted circuit will occur in the event of a short circuit, regardless of the instantaneous load situation.

Figure 5 shows a protective circuit in which a power transistor 4, [preferably] **e.g.** a MOSFET switching transistor having an integrated free-wheeling diode 7 is used. Power transistor 4 is controlled by a comparator 1 whose one input 6 receives a reference voltage Uref. Second input 5 of comparator 1 is connected between the series connection of resistors 2 and 3, resistor 2 being connected to terminal KL30 and resistor 3 being connected to terminal KL31. Terminal KL30 corresponds to the 12V or 14V terminal of a conventional on-board electrical system, while terminal KL31 corresponds to the ground line.

The mode of operation of the circuit may be explained as follows. The voltage on the 14V terminal is sent to ground terminal KL31 over the voltage divider having resistors 2 and

3. The voltage applied between two resistors 2 and 3 is measured and sent to the input of comparator 1 and compared with reference voltage Uref. Voltage U2 at resistor 3 drops as a function of the current flowing across resistors 2, 3[,]. If this voltage U2 sent to comparator 1 exceeds preselectable reference voltage Uref, power transistor 4 which is activated becomes conducting and therefore limits the voltage to the level defined by resistors 2 and 3. A certain voltage may thus be preselected through the choice of resistors 2 and 3. Power transistor 4 thus forms an active voltage limiter.

If the on-board electrical system is supplied with a negative voltage, reverse diode 7 of charging voltage is switched to conducting. Then the threshold voltage of reverse diode 7 is established as the maximum negative voltage in the on-board electrical system. This value may be preselected. The reverse diode thus assumes a protective function, which [has] **may have** the advantage in comparison with a possible combination with a Zener diode that a narrower tolerance band may be established for the voltage. The circuit in Figure 5 [makes] **may make** it possible to limit a short circuit as well as negative voltages to advantage.

[Abstract of the Disclosure] **<u>ABSTRACT OF THE DISCLOSURE</u>**

A multi-voltage on-board electrical system [having] **<u>including</u>** at least two voltages different from ground, e.g., 14V and 42V, is described, in which a generator, e.g., the electric generator of a vehicle, generates one of the voltages, and the other voltage is formed from the first voltage by a converter. The two voltages are used to supply two different d.c. systems. [Means are] **<u>An arrangement is</u>** provided as short-circuit protection between the two voltage levels, largely reducing the risk of a short circuit and/or the effects of a short circuit between the two voltages and/or protecting or disconnecting at-risk consumers in the event of a short circuit. In addition to the short-circuit protection, an overall concept of an electric battery and power management system [may] **<u>is</u>** also [be obtained] **<u>obtainable</u>** for the multi-voltage on-board electrical system.